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| **Project Title** | Mushroom Quality: Use of bruisometer to determine which agronomic and environmental factors affect bruisability. II. Effects of humidity, water potential of casing and casing type. |
| **Project Number** | M 40a |
| **Project Leader** | K.S. Burton, HRI Wellesbourne |
| **Report** | Final Report, November 2002 |
| **Previous Reports** | M 19a Validation of mushroom bruisometer (March, 1999)<br>M 37 The use of calcium chloride in the irrigation water to improve mushroom quality (April, 1999).<br>M 40. Mushroom quality: use of bruisometer to determine which agronomic and environmental factors affect bruisability. I. Effects of compost depth, casing depth and compost duration (November, 2000). |
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| **Date Project Commenced** | September 2001 |
| **Date Project Completed** | November 2002 |
| **Key words** | mushroom, *Agaricus bisporus*, quality, colour, bruising, compost, casing, humidity, watering |

# CONTENTS

# M 40a

# Mushroom Quality: Use of bruisometer to determine which agronomic and environmental factors affect bruisability: II Effect of humidity, water potential of casing and casing type.

## Headline

Mushroom bruising after harvest can be significantly reduced by how the mushrooms are grown.

- Humidity in growing houses and wetness of casing have major effects on bruisability but these effects vary with flush number.
- Least bruising occurred in first flush (grown wet), there was no difference in flush 2 and in flush 3 when grown dry.
- A checklist table has been produced showing which agronomic and environmental factors affect bruisability from this and previous projects.

## Background and expected deliverables

Mushroom quality is determined by colour, texture, uniformity and flavour. High quality mushrooms are ideally white in colour, firm textured, of uniform maturity and of good flavour. Probably the most important of these is colour. Mushrooms with brown discolouration are viewed as being 'old' and 'damaged' and therefore of low quality. Brown discolouration occurs due to either postharvest ageing or bruising during picking, packaging or transport. It is known that mushroom bruisability can vary from crop to crop or even within a crop due probably to differences in crop agronomy and environment. However, the factors which make mushrooms resistant or susceptible to bruising are not clear cut, and require experimental investigation to unravel.

Relevant work completed in previous projects (1998-2000)

### M 19a - Validation of mushroom bruisometer

Mushroom bruising occurs only on the outer surface of the mushroom cap and is largely caused by the mechanical force known as 'slip-shear' (downwards force and sideways movement). HRI in collaboration with the Mechanical Engineering Department of Coventry University underwent a design process to design and build a machine (bruisometer) to reproducibly simulate bruising by slip-shear. Prototype bruisometers were built and shown that they can distinguish between mushrooms of different bruisabilities. Specifications for use were identified and incorporated in the final design of bruisometer (handed to HRI in June 1999).

### M 37 - The use of calcium chloride in the irrigation water to improve mushroom quality

Calcium chloride irrigation had been reported to conserve the white colour of mushrooms in USA. This project assessed whether calcium chloride irrigation would have benefits for British grown mushrooms (which are generally considered to be of better quality). Mushrooms watered with the higher calcium chloride concentrations (0.4% and 0.5%) were whiter than the water control. These differences were identified by a sophisticated instrument (Minolta meter) but were not visible to many observers. However when mushrooms from the different treatments were subjected to a controlled bruising treatment, clear treatment differences (high calcium chloride concentrations mushrooms bruised least) could be identified by human observation as well as the Minolta meter. Therefore calcium chloride irrigation at the higher concentrations (0.4% and 0.5%) has been identified as reducing mushroom bruisability (but also caused the mushroom to mature at a faster rate).

### M 40 - Mushroom Quality: use of bruisometer to determine which agronomic and environmental factors affect bruisability. I. Effects of compost depth, casing depth and compost duration.

This, the first specific project examining which agronomic and environmental factors affect bruisability, looked at the effects of casing depth and compost depth (these factors were previously shown to greatly influence mushroom firmness) and compost composition. Mushrooms grown on shallow casing were substantially less bruisable than those from deeper casing (second flush only). Strawy, less degraded compost resulted in less bruisable mushrooms than the darker, more degraded composts. Compost depth had no effect on mushroom bruisability. As part of this project a trial was performed to determine the mushroom strain for experimentation. This trial confirmed large differences in bruisability between different strains.

This project (M 40a) and previous projects have examined a range of procedures/techniques used by mushroom growers and identified those agronomic and environmental factors that cause mushrooms to be highly susceptible to bruising when handled. Results from this work can be exploited by growers to produce more bruise resistant mushrooms by avoiding the agronomic/environmental procedures that cause mushrooms to be easily bruised.

## Summary of the project and main conclusions

Mushrooms were grown at three levels of casing wetness, two growing room humidities and two casing compositions, using the same compost and same mushroom strain. The bruisability of mushrooms from the different treatments were compared. All of the treatments used were well within the limits used by different farms in Britain. The casing wetness, nominally described as wet, medium and dry, was set at -12, -8 and -4 kPa. Growing room humidities were 85% and 92% relative humidity. The composition of the casings used was either 9% sugarbeet lime, 91% black peat or 30% sugarbeet lime, 70% black peat.

Casing wetness and growing room humidity had major effects on mushroom bruisability but this varied with crop flush. In summary, mushrooms grown in wet conditions at the start of the crop bruised the least (first flush mushrooms grown at high humidity and wet casing bruised the least of all / showed least discolouration, while third flush mushrooms grown in the drier conditions showed less bruising / discolouration than those grown under wet and medium wet conditions. No difference was found in second flush mushrooms between different casing water treatments.Second flush mushrooms grown at low humidity bruised more than those grown at high humidity.

In terms of casing composition a small but significant difference was detected. At dry water potential, the casing with 30% sugarbeet lime resulted in less bruising than the mushrooms grown in 9% sugarbeet lime i.e. if one is going to grow dry, use a high percentage sugarbeet lime to avoid easy bruising. There were no overall yield differences between treatments.

## Financial benefits

This project has identified growing procedures which determine mushrooms to be easily bruised or more bruise resistant. Use of this knowledge will allow growers to produce less bruised and therefore higher quality mushrooms which should lead to:

- Improved competitiveness *
- Improved prices *
- Less wastage/less packhouse time dealing with poor mushrooms
- Reduced need for postharvest washing

* It is recognised that under current conditions of import penetration due to the high £/€ rate, effects of this report on competitiveness and prices may be reduced.

## Action points for growers

Many possible agronomic and environmental influences on mushroom bruisability have been examined in a number of completed projects. It is sensible therefore to present all these results together in a table with their relative importances i.e. major, minor or no influence on mushroom bruisability. This table can be used by growers to identify why bruising is an occasional or regular problem on their farm and provide direction for remedial actions.

### Table 1. Environmental and Agronomic Factors shown to affect Mushroom Bruisability

| | Relative importance |
|---|---|
| • Water potential of casing | *** |
| • Humidity in growing room | *** |
| • Calcium chloride irrigation | ** |
| • Casing depth | ** |
| • Casing composition (% sugarbeet lime) | * |
| • Compost type | * |
| • Compost depth | - |
| • $CO_2$ level | nm |
| Also: | |
| • Flush | *** |
| • Strain | *** |

| | |
|---|---|
| *** | large influence on bruisability |
| ** | medium influence on bruisability |
| * | low influence on bruisability |
| - | no effect on bruisability |
| nm | not measured |

- If one has an occasional but low incidence problem with bruising, when this is identified in the packhouse, one should go back to the growing house and examine environmental data and conditions in the house and compare with the list in Table 1.
- If there is a regular but low percentage bruising problem, first check whether it is usually associated with a particular picker or house. It might be necessary to go into the houses to find if there are specific locations which lead to bruising (perhaps a local area of low humidity or poor watering).

- If the farm has a persistent and relatively high percentage bruising problem, then it might be worth considering a major overhaul of growing procedures. However, one should do this with the knowledge that the environmental and agronomic factors listed in Table 1 might also influence pinning, disease, crop timing and management.
- Mushroom strain has a major influence on bruisability. Changing strain may improve quality by lessening bruising (and, of course, it may make matters worse).

# Science Section

## Introduction

Quality is one of the main factors determining the competitiveness of the British mushroom industry. Mushrooms lose quality as a result of either ‘senescence’ (the process of natural deterioration in the hours and days after harvest), or mechanical damage (which results in rapid discoloration). HDC Project M 19 demonstrated that the mechanical process most damaging to mushrooms (in terms of bruising) is the process of ‘slip-shear’. An example of slip-shear is when a finger slides over the surface of a mushroom with some downwards force. This occurs during picking and to a lesser extent when mushrooms rub against each other before or after harvest.

Bruising by slip-shear leads to discoloration, first reddish then brown. Certain combinations of growing conditions appear to lead to mushrooms which are either highly susceptible or resistant to bruising. The agronomic and environmental factors (flush, watering, casing, compost, humidity, strain and $CO_2$) which determine resistance or susceptibility are not known because previously no machine has been available to exert a controlled amount of slip-shear force on to a mushroom (or any other item of produce).

HRI has been collaborating with the Mechanical Engineering Department of Coventry University in the design and building of two prototype bruisometers, devices to inflict a controlled amount of slip-shear force onto the surface of mushrooms. These bruisometers were released to HRI in June 1998. These bruisometers were validated (in HDC Project M 19a), i.e. they were shown that they could distinguish between mushrooms of different bruisabilities. Also the information of Project M 19a was used to make improvements to the design of the bruisometers. Further collaboration with Coventry University has led to an improved design bruisometer handed to HRI in June 1999.

The machine is being used to determine which agronomic and environmental factors most affect mushroom bruisability. It is expected that the bruisometer will become commercially available in the future for growers to use. However, this machine will be used initially as a research tool so that the key factors affecting bruisability can be determined.

HDC Project M 40 examined the effects of casing depth, compost depth and composting duration on mushroom bruisability. The results of this project showed that casing depth had a significant effect and compost duration had a minor effect on mushroom bruisability. Compost depth had no effect on bruisability. Second flush mushrooms grown on shallow (25 mm) casing were much less bruisable than those grown on deep (55 mm) casing. Also mushrooms grown on strawy more undegraded compost bruised less than those grown on more degraded compost.

The objectives of this current project are to further the understanding on the influences and control of mushroom bruising by examining the effects of humidity, watering and casing type on mushroom bruisability. These factors were varied using conditions and materials available to the industry so that the results can feed directly into farm management for improved product quality.

## Materials and Methods

Specific objectives of this project are:

1. Assess the effects of growing room humidity on mushroom bruisability.
2. Assess the effects of casing water potential on mushroom bruisability.
3. Assess the effects of casing composition on mushroom bruisability.
4. Examine any interactions between specific objectives 1, 2 or 3.

Mushrooms (strain A15) were grown on HRI formula III compost at the HRI Mushroom Unit, Wellesbourne. Compost was cased with one of two casing types and of three water potentials. The mushrooms were grown in chambers with different humidities. Mushrooms were harvested for three flushes from each of the treatment combinations. Mushrooms were subjected to a 200 g x 2 cycle bruising treatment, then held at 18°C, 90% relative humidity for two hours and then the colour of the bruise measured in 5 different positions using a Minolta meter. The use of humidity as a treatment requires different growing rooms. Two different humidities were examined. Two chambers per humidity treatment (ie. four chambers) were used in a 2 x 2 Latin Square. The results of bruise colour were statistically analysed by analysis of variance and analysis of co-variance..

A factorial crop experiment was performed with:
Two relative humidities (85% and 92%) X Three water potentials of the casing (Dry, Normal and Wet) X Two different casing types (9% sugar beet lime, 30% peat and 30% sugar beet lime, 70% peat). The number of treatment combinations were therefore 2 x 3 x 2 = 12. The whole experiment were replicated and two growing chambers were used for each humidity treatment. In each growing chamber, six stacks each of four trays were used (six from three water potentials X two casing types). Four growing chambers were used therefore the total number of trays used was 6 x 4 x 4 = 96 trays.

The relative humidities were achieved by the computerised controls associated with the chambers. The low humidity were set for 85% RH and the high humidity to 92% RH. These set points generated two ranges of relative humidity, 83-87% and 90-94% respectively.

Two of the water potentials of the casing were initially created by the volume of water added to the casing at the point of mixing. Water was added to achieve water potentials of -8 kPa (normal) and -4 kPa (wettish). The dry water potential (-12kPa) was initially achieved by allowing the casing mixtures to dry out in a growing room at 18°C for one week. These casings were monitored weekly by sampling followed by percentage moisture contents and reference to water release curves (provided by Dr Ralph Noble). The water potentials of the casings were adjusted by watering as required, i.e. the wet casing was maintained as wet throughout the crop, similarly medium and dry casings were maintained throughout.

Two types of casing were used: 9% sugar beet lime, 91% black wet-dug peat and 30% sugar beet lime, 70% black wet-dug peat.

Each of the three parameters (relative humidity, water potential of casing and casing type) were varied within the ranges used in the mushroom industry.

The mushrooms were grown using Standard Operating Procedures of the HRI Mushroom Unit unless stated otherwise.

The stacks of each treatment combination were randomised within each growing chamber. Mushrooms were harvested from each stack for three flushes. Fifteen clean white blemish-free mushrooms were selected for each harvest per stack and subjected to the bruising treatment of 200 g x 2 cycles. The mushrooms were placed cap uppermost so that the bruise colour developed in the environment of 18°C, 90% RH. After two hours the bruise colour of the mushrooms was measured using a Minolta meter 503i. Colour was measured on three points of the bruise (one at the top of the cap, one on each of the sides) and at two equivalent points (top and side) on the unbruised region of the cap. This procedure allows a comparison to be made between bruised and unbruised regions.

Statistical analyses were made of the colour data using analysis of variance (colour of bruise) and analysis of co-variance (bruise colour-unbruised colour) to look at the main effects (relative humidity, water potential of casing and casing type) and then look for interactions between main effects.

## Results and Discussion

These results relate to a major crop experiment which was factorial in design so all of the major treatment effects were examined as well as the effects of combinations of treatments. For ease of reading we have chosen to present these results under main treatment effects headings (i.e. humidity of growing room, water potential of casing and casing composition). However, it should be appreciated that the major statistical differences are found in the combination of main treatment effects and flush number (i.e. the main treatment effects differ for different flush number). On reflection, this is not surprising as if the effect of any agronomic/environmental factor was clear-cut across all flushes then it would have been obvious to the industry for many years. For clarity we have chosen to present only the 'L' colour values which represent the overall light or darkness (discolouration) rather than the opponent, colour scales ('a' - green to red or 'b' - blue to yellow). The higher the 'L' value the whiter the colour or the less discoloured the mushroom. In the tables below we have presented the data and the LSD (Least Significant Difference) between the mean. We have indicated significant differences by the symbols » or «. A significant difference in L value of greater than one unit is noticeable to the human eye in the range of 78-84.

### Effect of Humidity in growing room

Tables 2 and 3 show the effects of growing room humidity on the amount of colour in the bruised area for the side and top of the mushroom respectively. Second flush mushrooms grown in high humidity (92% RH) showed less discolouration i.e. higher 'L' value (tops and sides) after a bruising treatment than mushrooms grown in lower humidity. For first flush mushrooms, the tops discoloured less but there was no difference in the colour of the sides. There were no differences in the bruise colour between mushrooms grown in low or high humidity for third flush mushrooms.

### Effects of Water Potential of Casing

The effects of the casing water potential on the bruise colour are shown in tables 4 and 5 for sides and tops of mushrooms respectively. The two tables show the same pattern. First flush mushrooms grown in wet casing discoloured significantly less (higher L) than mushrooms grown in medium or dry casing. No significant differences were detected between different casing water treatments on second flush mushrooms. For the third flush, mushrooms grown on dry casing discoloured less than those from medium casing which in turn is less discoloured than from wet casing.

The beneficial effects of wet casing in the first flush is particularly pronounced in high humidity conditions but less so at low humidity.

**Effects of casing composition**

Tables 6 and 7 show the effects of casing composition and casing wetness on the bruise colour of mushrooms (flushes combined). In both tops and sides, the mushrooms grown on dry casing discoloured less if the casing contained 30% sugarbeet lime/70% peat rather than 9% sugarbeet lime/91% peat.

**Effect of Experimental Treatments on Mushroom Yields**

When the yields from the three flushes are combined, no overall treatment effect on yield was detected. However, as expected, yield varied with flush number (Table 8). Significant differences were observed in the interaction between watering treatments and the casing type for the yields of the first and second flush, these are shown in Tables 9 and 10 respectively. The third flush yields are shown in Table 11.

It is well known in the industry of an inverse relationship between yield and quality i.e. when yield is high quality is low and vice versa. No such relationship between bruise colour and yield has been found for treatments in this experiment. The results of which agronomic treatments cause high or low bruisability are therefore real and not an indirect effect of yield.

## Conclusions

The conclusions of the M 40a project are that casing water potential and growing room humidity have major effects on mushroom bruisability but these change with flush number, and casing composition has a minor effect on mushroom bruisability.

- First flush mushrooms grown on wet casing discoloured the least after a bruising treatment. No effect of casing water potential was found on the bruisability of second flush mushrooms. For the third flush the driest water potential produced the least bruised mushrooms.
- Second flush mushrooms and to a lesser extent first flush mushrooms discolour less when grown at high humidity.

- At dry water potential, mushrooms grown in 30% sugarbeet lime casing bruised less than when grown in 9% sugarbeet lime casing.

A summary of all of the results from this and previous projects is shown in Table 1.

## Technology Transfer

The results of this project were presented in a lecture by Kerry Burton at "Mushroom Day" at HRI, Wellesbourne, Thursday 20 June 2002.

The results will also be published in summary form in HDC News.

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**Table 2. Effect of growing room humidity on the bruise colour (L) at the side of mushroom (Analysis of co-variance). Note: the higher the L value, the whiter or less visible bruising.**

| | | **Humidity** | |
|---|---|---|---|
| | **Low -85% RH** | | **High -92% RH** |
| Flush One | 82.12 | | 82.02 |
| Flush Two | 79.92 | « | 82.20 |
| Flush Three | 80.08 | | 80.41 |

LSD = 0.9

**Table 3. Effect of growing room humidity on the bruise colour (L) at the top of mushroom (Analysis of co-variance). Note: the higher the L value, the whiter or less visible bruising.**

| | | **Humidity** | |
|---|---|---|---|
| | **Low -85% RH** | | **High -92% RH** |
| Flush One | 82.33 | « | 82.85 |
| Flush Two | 80.76 | « | 83.28 |
| Flush Three | 81.61 | | 82.03 |

LSD = 0.47

**Table 4. Effect of water potential of casing on the bruise colour (L) at the <u>side</u> of mushrooms (Analysis of variance). Note: the higher the L value, the whiter or less visible bruising.**

| | Casing Water Potential | | | | |
|---|---|---|---|---|---|
| | **Dry** | | **Medium** | | **Wet** |
| Flush One | 80.99 | | 80.95 | « | 83.02 |
| Flush Two | 81.19 | | 81.44 | | 81.06 |
| Flush Three | 81.14 | » | 80.09 | » | 79.03 |
| | | | | | LSD = 0.70 |

**Table 5. Effect of water potential of casing on the bruise colour (L) at the <u>top</u> of mushrooms (Analysis of variance). Note: the higher the L value, the whiter or less visible bruising.**

| | Casing Water Potential | | | | |
|---|---|---|---|---|---|
| | **Dry** | | **Medium** | | **Wet** |
| Flush One | 82.32 | | 82.20 | « | 83.65 |
| Flush Two | 81.89 | | 82.23 | | 82.03 |
| Flush Three | 82.95 | » | 81.57 | » | 80.45 |
| | | | | | LSD = 0.66 |

**Table 6. Effect of casing composition and water potential of casing on the bruise colour (L) at the side of the mushroom. Note: the higher the L value, the whiter or less visible bruising.**

| | Casing Composition | | |
|---|---|---|---|
| **Water potential of casing** | **9% sugarbeet lime/ 91% peat** | | **30% sugarbeet lime/ 70% peat** |
| Dry | 80.76 | « | 81.46 |
| Medium | 80.95 | | 80.71 |
| Wet | 81.13 | | 80.95 |
| | | | LSD = 0.57 |

**Table 7. Effect of casing composition and water potential of casing on the bruise colour (L) at the top of the mushroom. Note: the higher the L value, the whiter or less visible bruising.**

| | Casing Composition | | |
|---|---|---|---|
| **Water potential of casing** | **9% sugarbeet lime/ 91% peat** | | **30% sugarbeet lime/ 70% peat** |
| Dry | 81.71 | « | 83.07 |
| Medium | 82.25 | | 81.75 |
| Wet | 82.21 | | 81.88 |
| | | | LSD = 0.54 |

**Table 8. The yield of harvested mushrooms (kg/tonne) from combined treatments for each flush and total (3 flushes).**

| Flush One | Flush Two | Flush Three | Total |
|---|---|---|---|
| 127.5 | 119 | 47 | 293.5 |

**Table 9. The effect of casing composition and water potential of casing on yields of harvested mushrooms (kg/tonne) from first flush**

| | Casing Composition | |
|---|---|---|
| **Water potential of casing** | **9% sugarbeet lime/ 91% peat** | **30% sugarbeet lime/ 70% peat** |
| Dry | 90.5 | 138 |
| Medium | 135.5 | 145 |
| Wet | 133 | 123.5 |
| | | LSD = 13 |

**Table 10. The effect of casing composition and water potential of casing on yields of harvested mushrooms (kg/tonne) from second flush**

| | Casing Composition | |
|---|---|---|
| **Water potential of casing** | **9% sugarbeet lime/ 91% peat** | **30% sugarbeet lime/ 70% peat** |
| Dry | 137 | 108 |
| Medium | 107.5 | 113.5 |
| Wet | 127.5 | 120.5 |
| | | LSD = 11.5 |

**Table 11. The effect of casing composition and water potential of casing on yields of harvested mushrooms (kg/tonne) from third flush**

| | **Casing Composition** | |
|---|---|---|
| **Water potential of casing** | **9% sugarbeet lime/ 91% peat** | **30% sugarbeet lime/ 70% peat** |
| Dry | 48.3 | 48.6 |
| Medium | 47.4 | 44.0 |
| Wet | 51.1 | 41.3 |
| | | LSD = 16.6 |